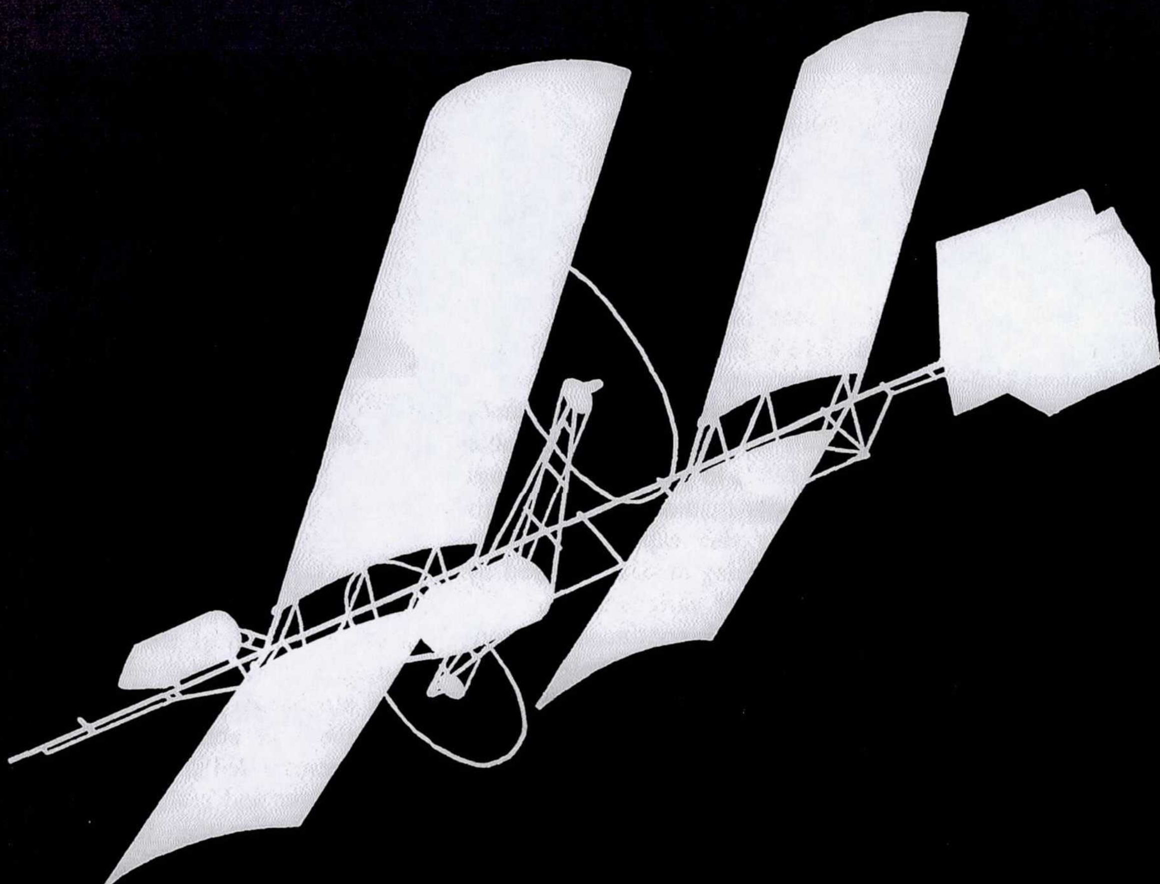
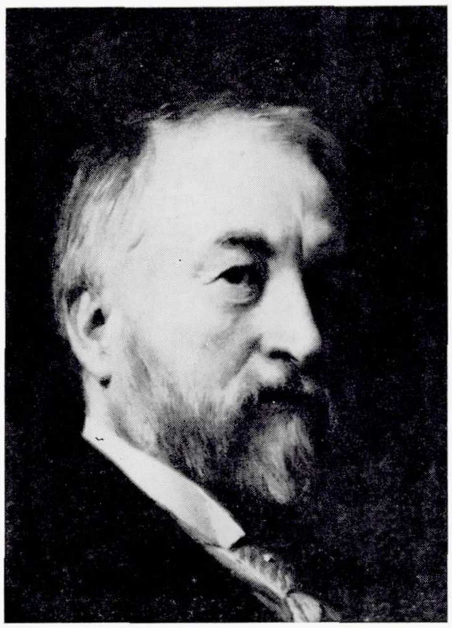


The 1962 Langley Memorial Lecture

On December 6, 1962, Dr. Raymond L. Bisplinghoff delivered the third in a series of Langley Memorial Lectures to the students of the Schools of Engineerings and Mines, University of Pittsburgh. The Lectures are held in honor of Professor Samuel P. Langley, former teacher of physics and astronomy at the University, and a past Secretary of the Smithsonian Institute in Washington, D. C.

About Samuel Pierpont Langley



PROF. SAMUEL PIERPONT LANGLEY
American Astronomer, Physicist, and Aeronautical Pioneer
1834-1906

In 1866 a 52-year-old professor of physics and astronomy at the University (then known as the Western University of Pennsylvania) began to study the gentle soaring flight of migratory whooping cranes. He had become interested in a work on their flight by Israel Lancasted; he could not rest until he had discovered how these birds could sustain themselves for hours in a seemingly effortless position. This curiosity of Professor Samuel Pierpont Langley was to lead him to achieving important feats. Professor Langley would be the one whose heavier-than-air flying machine would soar through the air before the Wright brothers were successful; he would be the one to prove a mistake in Newton's figures on resistance.

Professor Langley's feats were accomplished because he could grasp new relationships and would work hard to prove his theories, even though public opinion would be against his "silliness." The most important relationship that Professor Langley formulated sprang from his interest in the flight of the whooping crane. He realized that the flight of these birds was dependent upon a Newtonian Maxim which stated that the resistance of a plane surface to the air varies as the square of the sine of its angle of incidence. Now the hard work began.

Langley began to expand his experiments and apply the principle to a variety of surfaces. The result of this study was the issuance of a physical law by Langley which stated that Newton's figures on resistance were in error and that resistance was only 1/20 that stated by Newton. He further stated that mechanical flight was possible with engines then in existence.

In 1889 Professor Langley was named secretary of the Smithsonian Institute in Washington, D. C., and, as a result of this position, was able to secure funds to publish his writings on the heavier-than-air flight. At this time Langley also experimented with hundreds of flying models powered by many engines of various kinds.

The hard work continued; he constructed a small, very lightweight steam engine which operated with a low power to weight ratio; he worked long and hard on the development of suitable wings to carry the aerodrome. By 1894 he was experimenting on a flying model which was launched from atop a houseboat moored in the Potomac near Quantico. The wings of the poorly-balanced model were of silk, the framework of split bamboo. The fragile nature of the lightweight craft required a dead calm for launching—a situation rarely witnessed in a Virginia winter. The launching catapult was tricky and unreliable. These factors spelled immediate defeat for the first four models shot into the cold air. One by one the frail models strained at the catapult with the force of their tiny steam engines, and one by one they were cut loose, only to drop and sink beneath the deep, murky waters of the quiet river.

Success came in October, 1894. Aerodrome No. 5 was launched and maintained flight of three seconds which covered about 35 feet. The aerodrome weighed 22 pounds "flying-weight."

After much thought to the necessity of proper moments of rotation, a pair of tandem wings and a pair of crossed planes for the tail assembly was decided upon. The launching of No. 6, a 26-pound model which looked like a dragonfly, was a failure and the crash was attributed to a faulty launching. But the venerable old man with his shirtsleeves rolled up stood on the bank of the river and realized that his success was closer than it had been for years.

Dr. Alexander Graham Bell, a close friend of Professor Langley and a man who knew the hardships of fruitless research, was present at the launching of the rebuilt No. 5 equipped with tandem wings. The day was May 6, 1896. Langley and Bell had just finished a final check of the launching mechanism, the wings, the tail, and the engine of the aerodrome. They stood on the shore and looked out to the houseboat. Langley had been through one of the most difficult winters of his life. He had seen model after model collapse and sink. Newspapers had called him a madman, quack and dreamer. Through all the defeat he had retained his belief that powered flight was attainable in his time. Now Bell stood by, camera in hand, waiting to secure positive proof. The white-bearded astronomer waited until a few minutes after three and then shouted to the attendant on the houseboat, "Let her go." Then he held his breath.

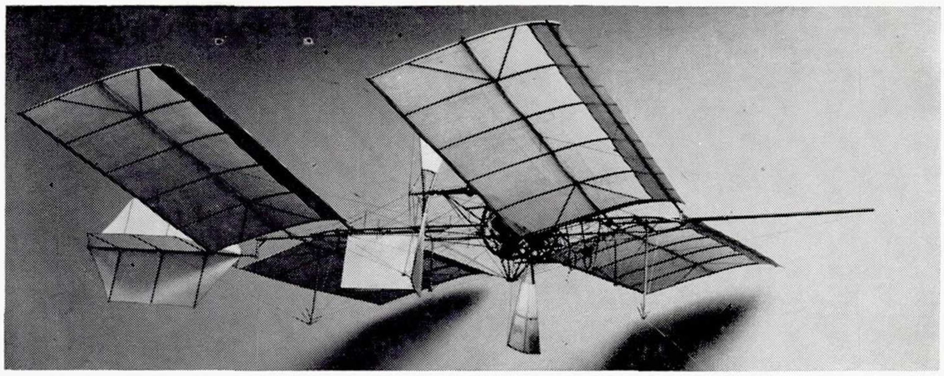
The propellers whirled madly, the

tiedown rope was cut, the aerodrome shot off the end of the catapult, dipped toward the water and then, to the shock and surprise of Langley, Bell and morbidly curious onlookers on the banks of the Potomac, it began to rise slowly in long graceful spirals. In the shouting and confusion, Bell forgot to take his historic pictures and hugged Langley excitedly. He later told reporters that he saw tears on the old man's cheeks.

The aerodrome remained airborne for 1 minute, 20 seconds, attained an altitude of between 70 and 100 feet and covered 3,000 feet. Immediately after the model was recovered safe and sound from the river, it was relaunched and flew again for 2,300 feet. A rebuilt No. 6 was launched in November of the same year and flew 4,200 feet at about 30 mph.

Professor Langley's curiosity had been satisfied. His principles had been proved. He stated publicly that the success of Aerodrome 5 and 6 marked the end "of the work which seemed to be especially mine—the demonstration of the practicability of mechanical flight—and for the next stage, which is the commercial and practical development of the idea, it is possible that the world may look to others."

The world, however, looked to Langley. In July, 1898, Gen. Adolphus W. Greely, chief of the United States Army Signal Corps, was sent to Smithsonian by President McKinley to request that Langley build an aerodrome suitable for combat duty. By the summer of 1903, the tandem-winged aerodrome, with a wing span of 48 feet and an overall length of 52 feet, was ready to be launched. It boasted a framework of steel tubing, bevel gear transmission, cotton-percaline-covered wings and two pusher propellers. The aerodrome used a split-vane rudder and an "equilibrium control," which trimmed the ship fore and aft. The pilot was able to adjust the engine in flight from his seat in front of the power plant. Lateral and vertical controls were mounted to the right and left of the exaggerated dihedral of the wings.


Langley's one-quarter size gasoline-engined model.

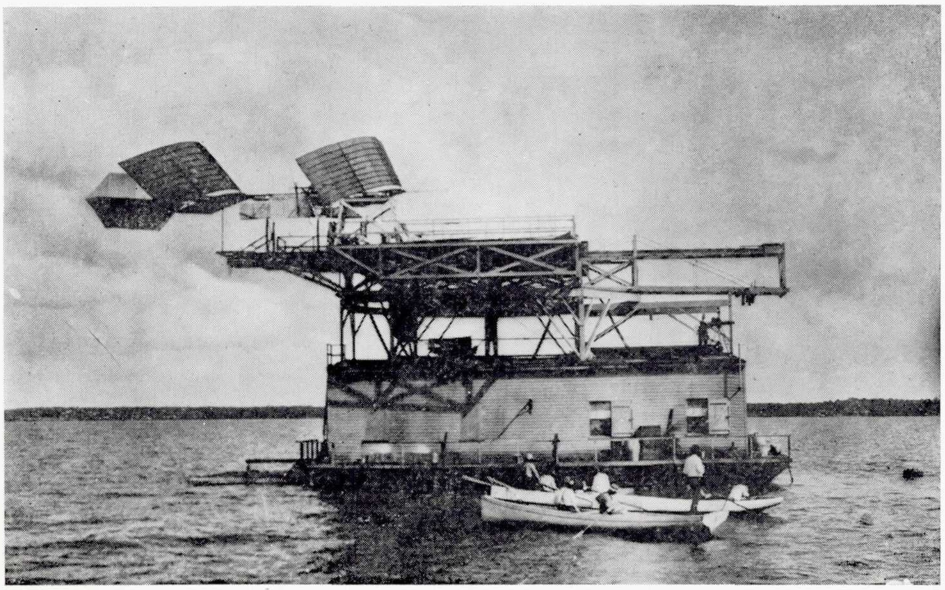
The aerodrome was mounted on the catapult and ready to launch, and there it sat for two months while storms lashed the Quantico area. Finally, on October 7, 1903, the launching was made. Professor Langley was detained in Washington for official business or, perhaps, merely used that excuse to hide from the waiting press, who had already expressed an open criticism of the government's waste of money on the experiment. Nevertheless, the launching was made, and the aeroship fell heavily from the end of the platform into the water. Manly, its pilot, was rescued unhurt and made a statement to the press in which he blamed a lack of balance in the airframe for the failure.

Although his heart was never in the new experiment, Langley took the latest failure as a personal defeat. His courage, however, would not be subjugated and through the constant and relentless persuasion of Manly, he repeated the fateful experiment of 1903. The latest attempt on January 6, 1906, resulted in the destruction of the machine, even before it left the catapult.

And so ended the experiments in flight by Professor Samuel Pierpont Langley — in failure. A short time after the failure of the fund-raising campaign for the last trial of Langley's man-carrying machine, the Wright brothers successfully made their flight at Kitty Hawk. When Professor Langley read of their success, he turned to Manly and said, "I must congratulate them." But the fire of curiosity and the burning desire to achieve powered flight were gone from Langley's eyes. He cleared his desk in the Smithsonian Institute and resigned his position.

On February 27, 1906, without fanfare or public attention, forgotten by the press which beat him to defeat and the crowds that waited to see him fail, Professor Langley died. He had never seen a man fly.

Eight years later, in 1914, a rebuilt model of the man-carrying aerodrome was successfully flown and landed on the waters of the Potomac, proving too late to the world that Professor Langley had achieved his dream and that only the world prevented him from seeing it.


AERODROME NO. 5 is poised on the launching catapult just before its first successful 3,000 foot flight.

DR. RAYMOND L. BISPLINGHOFF
Director, Office of Advanced Research and Technology National Aeronautics and Space Administration

About Dr. Raymond L. Bisplinghoff

The 1962 Langley Lecturer, Dr. Raymond L. Bisplinghoff, has had a distinguished academic and professional career that has led him to his present position of Director of the Office of Advanced Research and Technology of the National Aeronautics and Space Administration. He and the office that he heads marshal the planning, direction, execution, and evaluation of all NASA research and technological programs conducted primarily to demonstrate the feasibility of advanced concepts, structures, components or systems that may have general applications to the nation's aeronautical or space objectives.

Before coming to NASA Dr. Bisplinghoff taught at the Massachusetts Institute of Technology for 16 years, 10 years as Professor of Aeronautical Engineering, preceded by 4 years as Associate Professor and 2 years as Assistant Professor. His experience in aeronautical and space research includes a long association with the Department of Defense, NASA, and its predecessor, the National Advisory Committee for Aeronautics. Dr. Bisplinghoff served as Chairman of the NACA Subcommittee on Vibration and Flutter from 1948 to 1951. He has also participated as a member of the NACA Committee on Aircraft Construction, NACA Subcommittee on Aircraft Structures, NACA Committee on Aircraft, Missile, and Spacecraft Construction and the NASA Committee on Aircraft Structures.

He graduated from Hamilton High School in his hometown of Hamilton, Ohio; attended the University of Cincinnati, Cincinnati, Ohio; earned his Aeronautical Engineer degree, an M.S. in Physics and accumulated 60 graduate credits toward a Ph.D. in Physics before his work at Cincinnati was interrupted by World War II.

After the war Dr. Bisplinghoff received the degree of Sc.D. from the Swiss Federal Institute of Technology, Zurich, in 1957. He audited numerous courses in mathematics, mechanics, and engineering at the Massachusetts Institute of Technology.

An engineer for Aeronca Aircraft Corporation from 1937 to 1940, Bisplinghoff worked in stress analysis, design, aerodynamics, and flight testing. The following eight months he was engaged in aircraft structural and engine vibration work with the Vibration and Flutter Unit at Wright Field. Afterward he spent a year as Research Associate at the University of Cincinnati in x-ray diffraction research. He then served the University for two more years as Instructor of Aeronautical Engineering.

Dr. Bisplinghoff entered the Navy in 1943, and supervised research in the Applied Loads and Structural Dynamics Sections of the Structures Branch, Bureau of Aeronautics in the Navy Department. During the war he was a member of the Army-Navy-Civil Committee on Strength of Aircraft Elements, the Army-Navy-Civil Committee on Ground Loads for Airplanes, Army-Navy-Civil Committee on Water Loads for Seaplanes, and the Army-Navy-Civil Committee on Design of Wood Aircraft Structures.

From 1946 until 1962 Dr. Bisplinghoff was at M.I.T. where he became Deputy Head of the Department of Aeronautical Engineering in 1953. He was a National Science Foundation Senior Post Doctoral Fellow in 1956 and 1957 while on sabbatical leave from M.I.T. As representative from M.I.T. for Operation Greenhouse he earned the Certificate of Achievement from the United States Air Force for his aid in predicting the effects on aircraft of a series of atomic bomb tests in the South Pacific.

Dr. Bisplinghoff's professional affiliations include membership in Phi Eta Sigma, Tau Beta Pi, and Sigma Xi fraternities. He is a member of the American Society for Engineering Education and a fellow of the American Association for Advancement of Science. A fellow of the Institute of the Aeronautical Sciences, and former Chairman of the Boston Chapter, Dr. Bisplinghoff has received from I.A.S. the Sylvanus Albert Reed Award for a notable contribution to the aeronautical sciences; he was the Institute's nineteenth Wright Brothers Lecturer in 1955. He is also a fellow of the Royal Aeronautical Society and the American Academy of Arts and Sciences. He is a member of the Association of Former Students of the Swiss Federal Institute of Technology.

The author or co-author of more than two dozen published papers, reports, and books, Dr. Bisplinghoff has also been Chairman of the Aeroelasticity Panel of the Institute of the Aerospace Sciences. During the past ten years he has consulted at various times for the Clifford Manufacturing Co., Piper Aircraft Corp., Chance Vought Aircraft Corporation, Boeing Airplane Co., Kaman Helicopter Corp., Sylvania Manufacturing Co., Allied Research Associates, John Wiley & Sons, McGraw-Hill and Addison Wesley Publishing Companies, National Research Corp., White Sands Missile Range, U. S. Army, and the General Electric Co.

Dr. Bisplinghoff and his wife, Ruth, live with their two sons, Ross Lee and Ron Sprague, in Alexandria, Virginia.

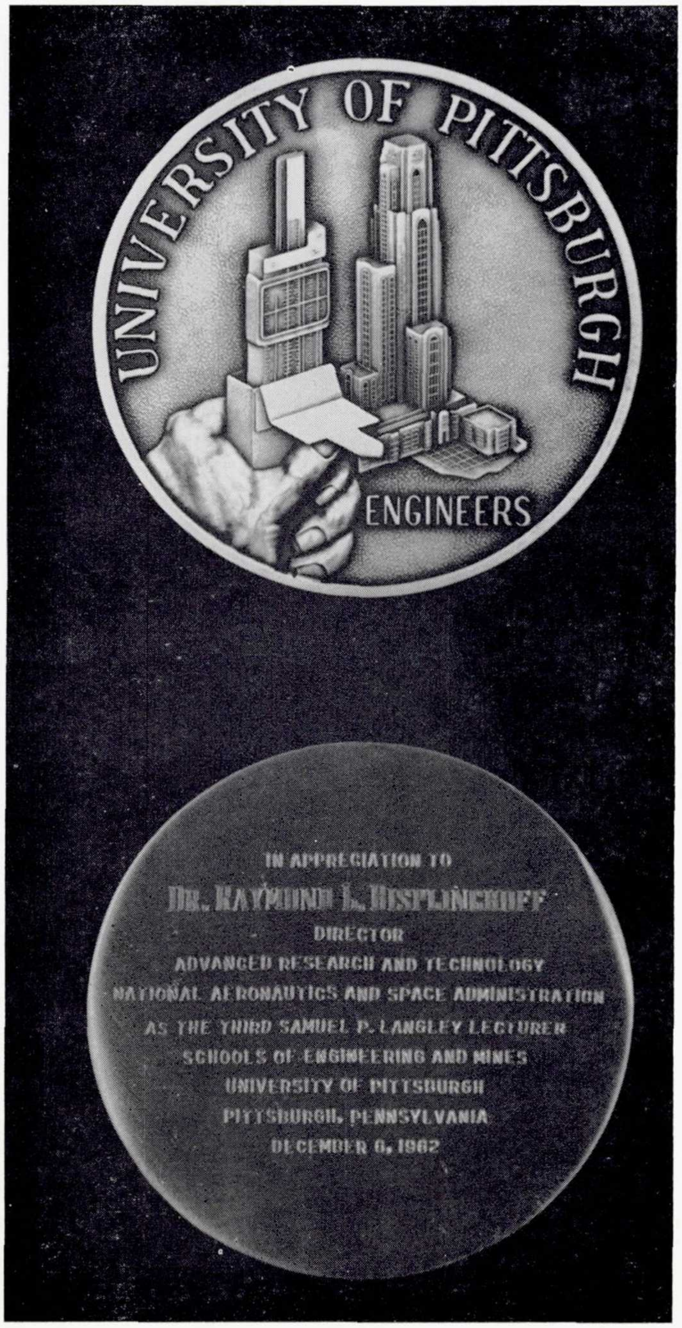
The University of Pittsburgh

1962 Langley Memorial Lecture

by

Raymond L. Bisplinghoff

Soldiers and Sailors Memorial Hall
December 6, 1962



The Samuel P. Langley Memorial Lecture, sponsored by your engineering school, has earned the recognition of an auspicious event. It is indeed an honor to be asked to carry forward the high traditions which have been set by the previous lecturers commencing with Dr. Paul D. Foote in 1958.

Meeting with you today is a most satisfying experience since I spent so many years of my own career in a university community. It is especially gratifying to renew acquaintances with Dean Fitterer and members of the University of Pittsburgh engineering school faculty.

As you might expect in a lecture sponsored by your engineering school in the memory of Samuel P. Langley, I shall devote my attention to science and engineering as they relate to aeronautics and space. I cannot, however, refrain from some *conjecture* at the outset on how Dr. Langley would be delighted with this topic and with the age in which we live. It is difficult to find in any generation a man whose contributions coincide more closely than those of Samuel P. Langley with the broad sweep of science and technology now emerging in our national aeronautics and space program.

The history of Langley's career is a lesson in versatility, perseverance, and steadfast courage. This man, who became one of the nation's leading scientists, had no formal education other than a high school diploma from Boston Latin in 1851. He also pursued a period of self study in the Boston libraries and with this preparation he went in 1857 to the west where he practiced civil engineering in Chicago and St. Louis. His liberal education was in a sense completed in 1864 by a year's trip to Europe with his brother. I do not necessarily condone Dr. Langley's choice of a process of education, but I believe that his success in spite of it could serve as an inspiration. Langley returned from Europe with a strong desire to become an astronomer, a career which he began as an assistant in the Harvard observatory. At the age of 33 he was named director of the Allegheny Observatory of the University of Pittsburgh

LEFT: Both faces of the medallion which is presented to the speaker who delivers the Langley Memorial Lecture.

CONTACT IONIZATION TYPE OF ION ENGINE

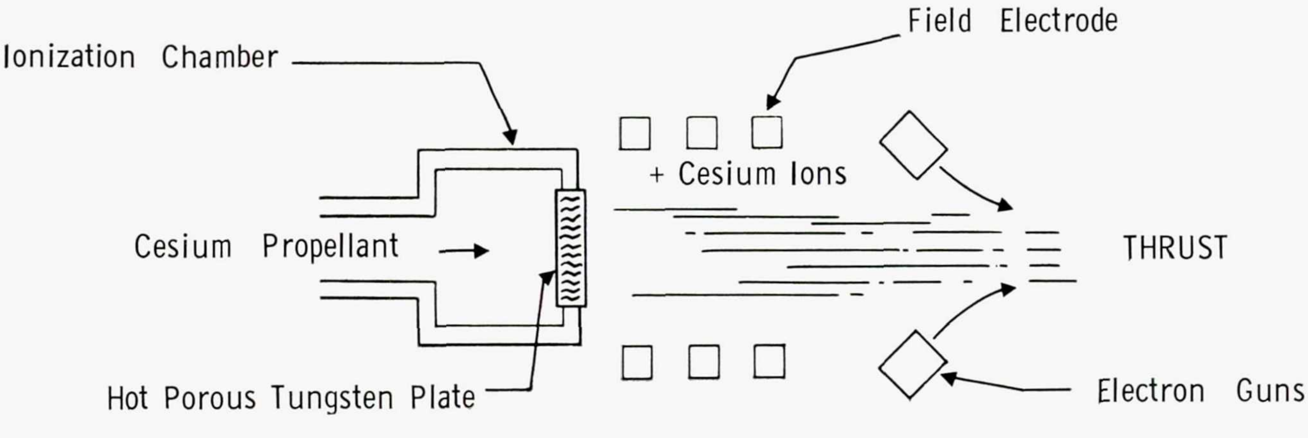


Figure I

langley lecture

where he remained for 20 productive years until he assumed the highly responsible office of Secretary of the Smithsonian Institution in Washington.

While at the Allegheny Observatory, Samuel P. Langley was an ardent student of solar phenomena, and he is remembered for his exquisite drawings of the great sun spot of December, 1873. He was intensely interested for many years in the fundamental problem of the amount of heat the earth receives from the sun and the selective absorption of it by the earth's atmosphere. Langley's interest in the sun led him to the invention of an instrument known as the "bolometer," used to measure the properties of the solar spectrum. While he was still at Allegheny he became interested in the science of aerodynamics and constructed, with the financial aid of William Thaw of Pittsburgh, a whirling table for experimental studies of this new science on the lawn of the observatory. In his own words it was "of unprecedented size, mounted in the open air and driven round by a steam engine, so that the end of its revolving arm swept through a circumference of 200 feet at all speeds up to 70 miles an hour." There Langley came to the conclusion, as his experiments continued, that mechanical flight was possible with the engines then available.

When he assumed his new post at the Smithsonian Institution, he continued studies and experiments in both aerodynamics and astronomy in spite of the many administrative duties which were required of him. His work in aerodynamics was widely published and it inspired others to work in the field of mechanical flight. In fact, Wilbur Wright later wrote in a letter to Octave Chanute that "the knowledge that the head of the most prominent scientific institution of America believed in the possibility of human flight was one of the influences that led us to undertake the preliminary investigation that preceded our active work."

It is in the latter period of Langley's career that his perseverance and courage are most evident. He began in 1893 a three year period of determined effort which culminated in a successful flight in 1896 of a steam driven model airplane over a distance of 4,200 feet. He thus showed the world that a heavier-than-air model could be successfully flown some seven years before the Wright Brothers man-carrying flight of 1903.

This would have, in all likelihood, been the end of Langley's aeronautical experiments had it not been for a national emergency. This was war with Spain, and it brought an invitation from President McKinley in 1898 to construct a flying machine as a weapon of war. Again Langley summoned his strength for a period of sustained effort which was to witness two heart-breaking failures to fly his own machines and to end in his death in 1906 without having reached his goal.

We are told that Langley's unsuccessful experiments cost the United States government some \$70,000. We can also discern over the years some feeling for the opprobrium which was leveled against this visionary man. A particularly cruel newspaperman wrote, for example: "here is \$100,000 of the people's money wasted on this scientific aerial navigation experiment because some man, perchance a professor wandering in his dreams, was able to impress officers that his scheme had utility." One cannot help but compare the attitude of Langley's day toward scientific experimentation with that of today in which billions are spent on research and development.

Despite the pioneer efforts of Langley and the Wright Brothers, the European countries forged ahead in the development of aircraft design and technology prior to World

War I. To deal with this deficiency, we established in 1915 the National Advisory Committee for Aeronautics, the predecessor of the National Aeronautics and Space Administration, with a $5,000 annual budget attached as a rider to the Naval Appropriations Act of that year. It was charged with the conduct of research to advance aeronautics. We can say that this was our country's first step into so-called big science.

In the early years of this century, another American, Robert H. Goddard, carried forward the pioneer work in the development of the rocket and demonstrated that a rocket, carrying its own oxygen supply, could provide thrust in a vacuum. But again it was European countries, Germany and the Soviet Union, which built the first hardware capitalizing on this principle for military purposes.

These and other examples have demonstrated that our country cannot afford to lag in the advancement of human knowledge. Clearly a nation with the responsibilities of ours in today's world must continue to pursue knowledge to provide assurance that it will fulfill its responsibilities. As the realization of this truth has grown since World War II, the participation of the National Government in research and development has expanded in geometric progression. At the turn of the century the sum was less than 10 million dollars a year. At the beginning of World War II, Federal outlays for research and development were still under 100 million dollars a year. Consider now these figures: one billion dollars in 1945, two billions in 1953, three and a half billions in 1956, twelve and a half billions in the current fiscal year, which began July 1st.

Activities in space are responsible for more than half of the nine-billion dollar increase in Federal research and development outlays since 1956. The current space budget is about 5.4 billion dollars, of which just under 3.7 billion will be obligated by the National Aeronautics and Space Administration for aeronautics and space research and operations. The Department of Defense space budget is 1.5 billion, and the remainder will be expended by the Atomic Energy Commission, the Weather Bureau, and the National Science Foundation.

You are all undoubtedly familiar with the NASA work on orbiting satellites and space probes as well as the projects of manned space flight. The solid and enduring substance of space applications represented by the communications and meteorological satellites is recognized by all discerning people. The highly successful and spectacular manned orbital flights of Project Mercury have been given wide publicity. The aspirations of Project Apollo to land men

SCHEMATIC OF RANKINE CYCLE NUCLEAR - TURBOELECTRIC SPACE POWER SYSTEM

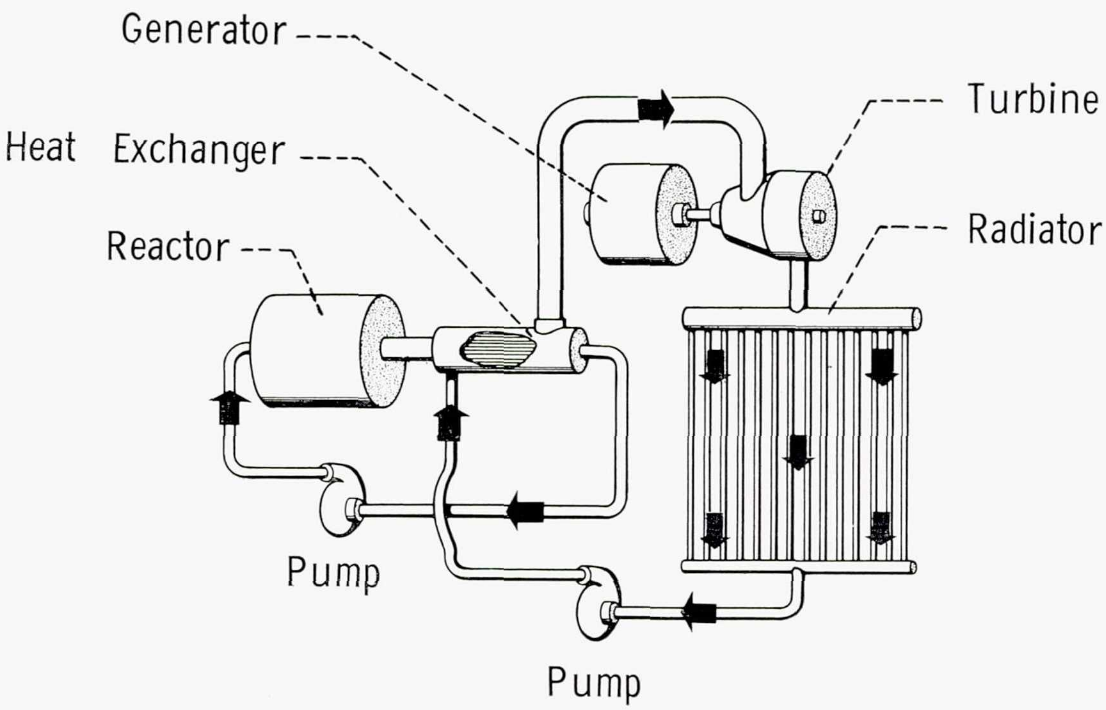


Figure 2

on the moon and return them in this decade have fired the imaginations of many. If Langley were a contemporary American citizen, I am sure that he would be proud of these bold plans and exploits.

However, there is another relatively unpublicized side of NASA's work, that of advanced research, which I would like to talk about today and which I am certain would also receive Langley's warm approbation. We are often asked, "Why is advanced research required?" The answer to this question has been given repeatedly by the lessons of history of science and technology. These lessons have taught that for pre-eminence, any branch of technology must embrace both fundamental research as well as applications of this research to projects for the benefit and use of man. The projects, which in the NASA example are the satellites and manned missions, rest upon the intellectual activity of research conducted in previous days and years. The intellectual activity of the research of today derives vigor and freshness from the motivations of the projects. For continued progress there is an immutable coupling between the two, and the absence of one produces sterility in the other. These assertions must certainly apply to large technological enterprises as well as small although our observations have been confined for the most part to the smaller entities such as industrial firms. Industrial firms have learned that continued progress cannot depend alone upon salesmanship based upon yesterday's technology, but that a sharp cutting edge of advanced research and technology is a necessary ingredient. The successful American company, based upon the exploitation of a single, perhaps patentable, idea is familiar. The idea may be codified carefully in guarded notebooks and in the minds of chosen executives. High dividends may be paid to the stockholders and enlightened employee benefits given. The management may be conducted according to an organization chart which is carefully designed. The company executives may be pillars of the community who make substantial contributions to all political and civic organizations. Nevertheless the company drifts slowly into bankruptcy because it is unwilling to expend a sufficient fraction of its profits to bring along new ideas as replacements for the original. So it is, I believe, with all technological enterprises whether they be measured at the unit of an individual, a company, a government bureau, or a nation.

I would like to outline for you in a general way some examples of the pathways of advanced research which must be followed during the 1960's if we are to stand foremost among nations in aeronautics and space activities in the 1970's. There are four areas where I would suggest that a continuing and driving program of advanced research is required if we are to achieve pre-eminence in aeronautical and space activities in the future. These are:

(1) Energy conversion and propulsion
(2) Materials and structures
(3) Control, guidance, and communications
(4) Space sciences and the environment of space

The challenge of the future which is presented to us in the area of energy conversion and propulsion embraces the most difficult technical problems ever faced by mankind. Man's efforts to propel himself along the surface and above the earth have always involved an energy conversion cycle which converts energy supplied by nature into thrust or torque. In modern aeronautical and space vehicles we are, in general, interested in two types of energy converters. The first is a propulsion device which supplies thrust and the second is an on-board power supply. The three principal sources of energy are chemical, solar, and nuclear. All three are exploited in advanced research in our national space program.

As you are no doubt aware, the largest existing space boosters make use of the energy contained in the propellant combination of liquid oxygen and kerosene. The growing need for more powerful and efficient chemical engines has spurred research into higher-energy combinations such as oxygen and hydrogen, fluorine and hydrogen, or fluorine and hydrazine. These propellants are viewed at the present time as being especially promising for employment in upper rocket stages. However, the most promise for increasing performance of upper stages is believed to rest in the nuclear rocket which is undergoing development as Project ROVER under the joint sponsorship of the AEC and NASA. The nuclear rocket employs fixed fuel elements containing uranium-235. Propellants like hydrogen or helium are pumped past the fuel elements and are heated to temperatures which approach 6,000°R. The heated propellants expand as gases through a nozzle to produce thrust. On November 30, 1962, a successful test of a nuclear rocket engine was conducted at the Nuclear Rocket Development Station in Nevada. Flights of the nuclear rocket are planned in the latter period of the 1960's.

The field of electric propulsion is being given very strong support in our national space program. Such electrical thrusters as ion rockets, one type of which is illustrated schematically by *Figure 1,* could impart over periods of months and even years accelerations on the order of 10^{-5} or 10^{-4}g to space vehicles. The ion engine illustrated by Figure 1 is known as the contact ionization type. Cesium propellant is passed through a porous hot tungsten plate which extracts an electron from each cesium atom producing positive cesium ions. The ions are accelerated by field electrodes and prior to exit from the engine are neutralized by the addition of electrons through an electron gun. Electric thrust devices require, of course, on-board electrical generators. For small engines requiring power of the order of 3 kw, solar or isotopic electric power generating systems may be employed. For higher powers, nuclear-electric power generating systems must be used. Such systems are under active development. An illustration of a double loop Rankine cycle space nuclear-turbo-electric power system is shown schematically by *Figure 2*. This system is similar in concept to those under development in the national space program. Such systems must employ liquid metals as the working fluids. For advanced electric thrusters, nuclear-electric space power systems in the power range of tens of megawatts will be required. The difficulties which must be overcome here may be appreciated when it is realized that these systems must weigh less than 20 pounds per kilowatt and operate reliably over periods of months and years.

The opportunities for ingenuity in affecting energy conversion in space are limitless. Fuel cells are an example of a concept which is being vigorously pursued. They are electrochemical devices like batteries except that the reactants are supplied to the cells from external tanks. One version of our fuel cell research involves the employment of human waste as an energy source. Along the same lines we are developing a bio-battery in which biological activity changes an unreactive chemical into one where electrical energy is obtained.

Man's engineering achievements have always been inextricably linked with his ability to use the materials furnished by nature. A decade ago, before we had capabilities of launching spacecraft or of operating aircraft at high supersonic speeds, the engineering demands could be satisfied with relatively few classes of materials. Furthermore, aircraft did not experience conditions drastically different from those of other machines such as locomotives, automobiles, or ships. With the arrival of space vehicles and supersonic aircraft, many new materials requirements have arisen. In most instances, the materials used in the older technologies could not be adapted to the new needs. Consequently, new approaches using entirely new classes of materials had to be found.

Materials research extends, more than the other basic research activities, over a wide range from the study of physical principles to applications in the space program. The materials problem may be connected with a tank in a launch vehicle, a heat radiator in space or a re-entry body, or it might be concerned with the theoretical understanding of surface phenomena and crystalline structures. It is inherent in studies of interplanetary travel and re-entry where the main concern is extreme environments: low and high temperatures, vacuum of space, and high launch and re-entry forces.

One of the most refreshing by-products of our space program might be termed "materials gadgeteering." It has long been the desire of metallurgists to engineer a material to meet specific requirements. To a limited extent, this is now possible. For example, rocket nozzle throat material requires a combination of strength and thermal conductivity. A metal, which in a pure state does not have the desired characteristics, may be conventionally strengthened by the addition of alloying materials. However, in almost all cases,

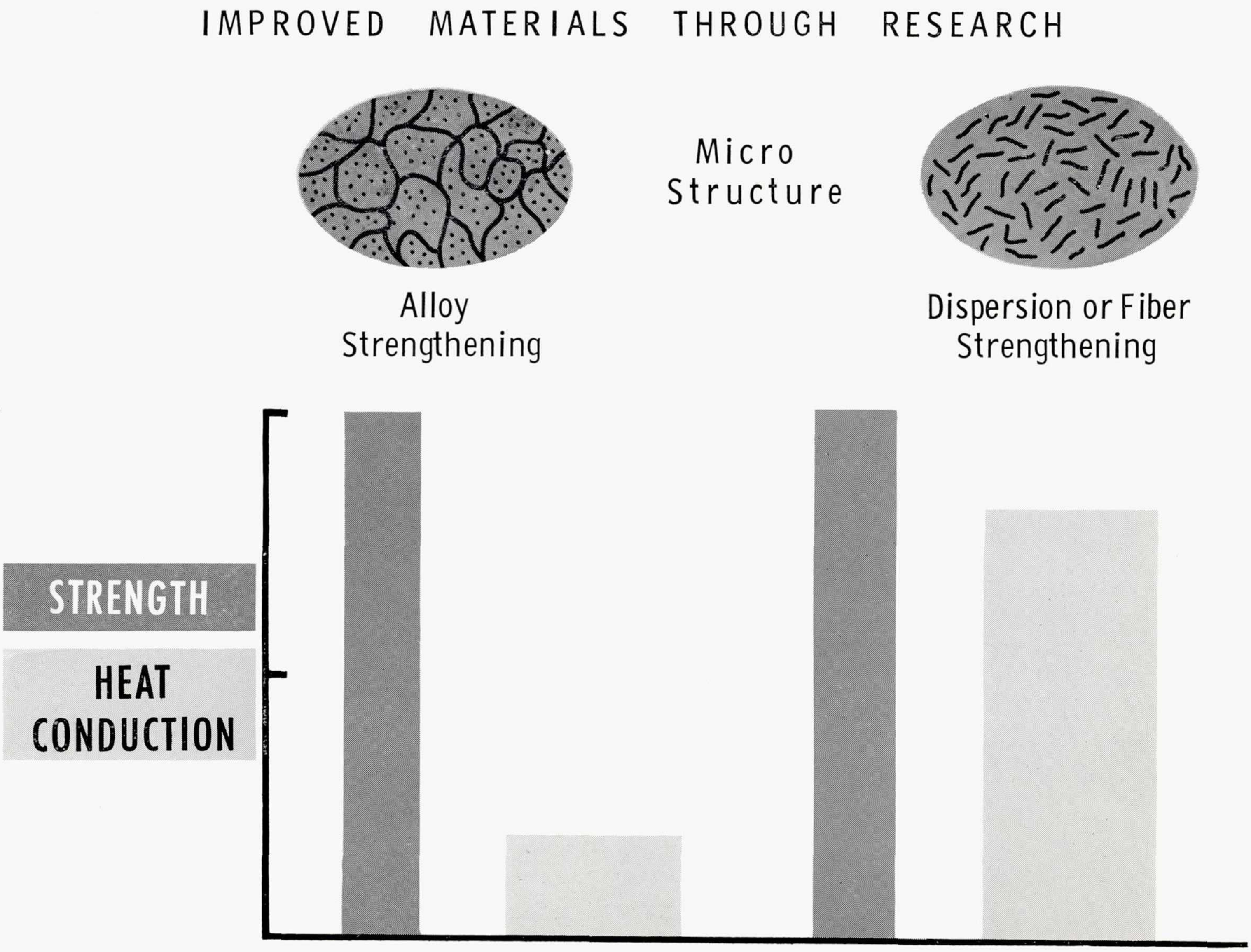


Figure 3

the thermal conductivity is drastically reduced which leads to cooling difficulties and therefore to wall destruction. Intense research efforts are being devoted to combining high strength with high thermal conductivity. One method of accomplishing this is by fibre strengthened alloys as illustrated by *Figure 3* in which many small fibres are mixed in the material, such as aluminum oxide fibres in aluminum. We find that fibre strengthened materials may have the same strength but many times the heat conductivity of a conventional material.

A materials problem which is of great urgency in our space program is that posted by the storage of cryogenic liquids. Storage of liquid oxygen at $-300°F$ in tanks creates serious problems. For example, if certain tank materials are struck, even mildly, when full of liquid oxygen, violent reactions including fire and explosion can result. Since our tanks may be struck by micro-meteoroids or subjected to severe vibrations we must find tank materials which are not reactive with liquid oxygen under impact. We are very hard at work in attempting to understand the nature and prevention of these reactions.

The most efficient space vehicle would be useless if it could not be controlled, guided, and communicated with in space. The heart of a control and guidance system is the gyroscope, an object which has been improved continuously over the past decade. Reliable inertial gyro units with drift rates of one minute per hour have been developed. The difficulty of this task was emphasized by C. S. Draper when he pointed out that such a drift rate requires a center of mass deviation of the gyro of less than fifteen crystal lattice dimensions of the material employed for gyro construction. Attempts to further improve gyros have led us along several pathways, one of which is toward the cryogenic gyroscope. The cryogenic gyroscope utilizes the phenomenon of superconductivity discovered by the Dutch physicist Onnes in 1911. Onnes discovered that the electrical resistance of some supercooled metals vanishes near absolute zero. In the 1950's, Matthias of the Bell Telephone Laboratories and Bardeen of the University of Illinois succeeded in cataloguing a number of superconductor materials and in improving the understanding of the phenomenon.

We are attempting to put this phenomenon to work by making a metal sphere levitate in a vacuum. If this can be done, a gyroscopic mass can be suspended in an almost frictionless environment. Once "spun up" to gyroscopic speed, the run-down time constant is expected to be meas-

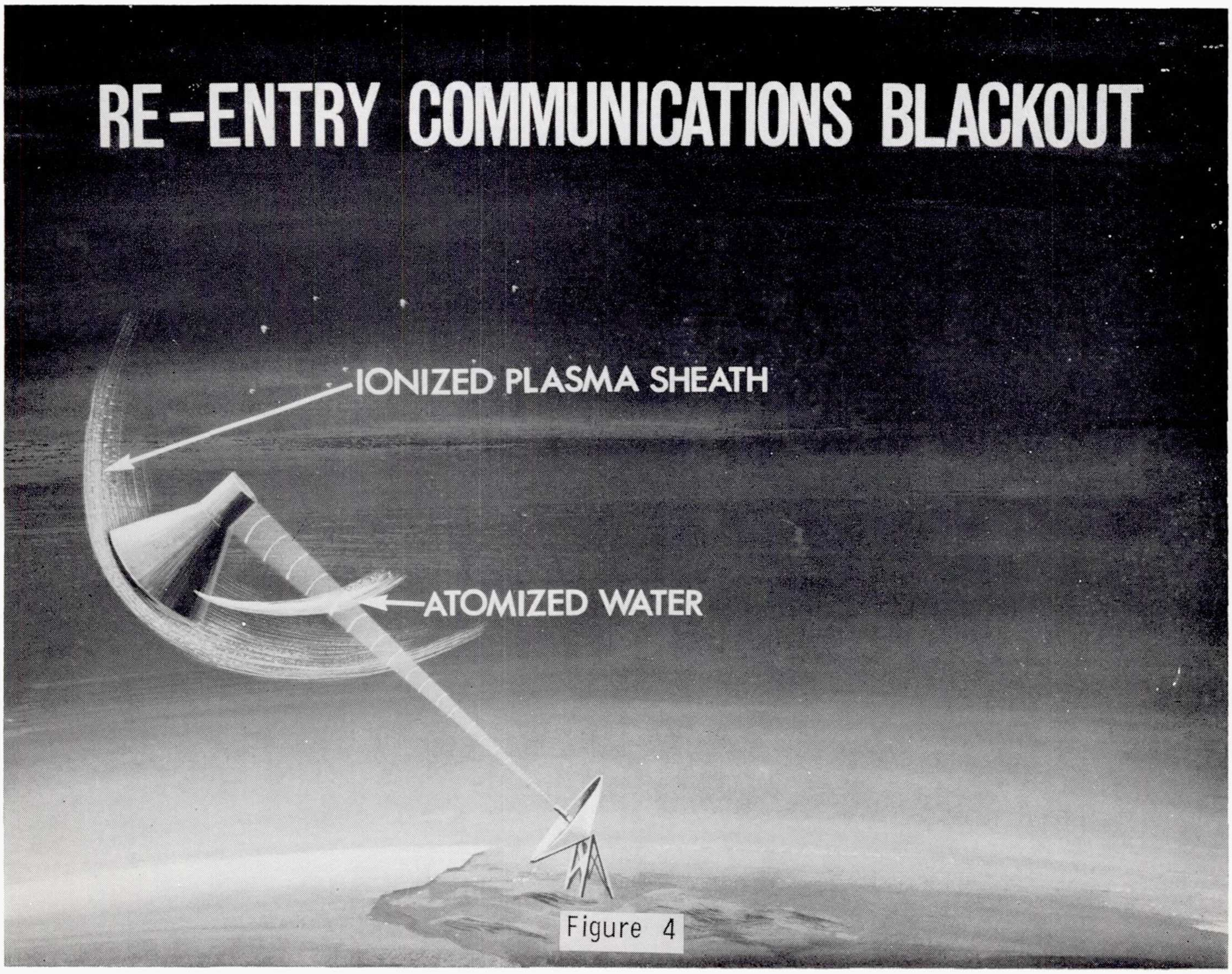


Figure 4

ured in years. The levitation is accomplished by surrounding the sphere with suitable magnetic fields so that a current is induced in the sphere. Since the sphere is a superconductor, the current continues without variation indefinitely. If the sphere is off center, non-equal repulsive forces will develop which cause it to "ride" the geometric center of the external fields.

During the historic flights of Colonel John Glenn and others we have all been made painfully aware of the communications black-out which occurs during re-entry. This is due to the inability of radio-frequency waves to penetrate the ionized plasma sheath which surrounds the spacecraft as it is aerodynamically heated in the earth's atmosphere. For some time, we have attempted to find a greater understanding of the problem and means of alleviating it. We now have evidence that very small amounts of atomized water injected into the ionized flow field as illustrated by *Figure 4* appear to act as a catalyst in reducing the electron concentration. This and other means of overcoming the communications blackout problem are being studied in theory and in shock tubes on the ground and in flight.

The area of space science is so vast that I cannot dwell long enough here to establish its true identity. When the term "space science" is used we infer "science in space." The word science is employed along the lines of the German equivalent *Wissenschaft,* meaning general knowledge of or learning about.

It is the area which has moved forward most dramatically during the past few years because of man's newly found ability to peer with satellites, sounding rockets, and space probes beyond the earth's atmospheric blanket. It is an area which is more properly the province of liberal arts colleges in modern universities, the departments of physics, astronomy, and geology being most intimately involved.

During the first four years of its existence, NASA launched 157 sounding rockets and 55 satellites, all of which were intended to gather geophysical and astronomical data. As a result, our knowledge of the density and composition of the upper atmosphere has increased greatly. Prior to the start of the International Geophysical Year, this knowledge was limited, for the most part, to altitudes below 100 km. At the present time, we are able to deduce through a combination sounding rocket-satellite experiment and theoretical arguments the essential properties of the atmosphere up to 1,000 km. This information has great value in understanding the solar influence on our atmosphere, incidentally one of Dr. Langley's early interests, and hence in understanding the causes of weather activity in the lower atmosphere.

The potential values of orbiting telescopes in extending astronomical observations beyond the earth's atmosphere are very great. This is certainly the first step toward a fuller understanding of the structure of stars and galaxies and even of stellar evolution. It seems strange that an orbiting satellite can be employed to obtain knowledge of the interior properties of the earth. Such knowledge, as those of you who study physics know, is extracted from an examination of the precise shape of the satellite orbit. This shape is governed by the gravitational field in which the satellite moves and is hence related to the distribution of mass within the earth.

Interplanetary space has been a region of rapid development of understanding in space science in recent months. In the first four years of NASA's existence some 9 space probes have been launched, the most recent being Mariner II now expected to pass within 21,000 miles of Venus at noon P.S.T. on December 14, 1962. Magnetic fields and the motions of interplanetary plasma as well as the particulate content of interplanetary space are all objects of study in these experiments.

I have spoken at some length about the technical challenge which faces our nation if we wish to establish and maintain a position of world pre-eminence in aeronautics and space activities. There is, however, a necessary condition which must be met in order to meet this challenge. This is the condition that there be available a sufficient supply of well educated and creative scientists and engineers. Recognizing the seriousness of the requirement for scientific manpower, the NASA has initiated a new program of grants to universities to help in the graduate training of outstanding students in space related science and technology. The first 100 students entered the program this fall—ten at each of ten selected universities. We expect that the scope of this program will grow.

Since this lecture is sponsored by your engineering school, I should like to conclude by outlining the challenge which faces the faculty and student body of this school. The requirements and standards which society places upon the engineer in 1962 are exceptionally high—so high that few who practice the profession truly fulfill them. What are the reasons for this? A necessary requirement in the education of a modern engineer is depth in science and mathematics. This alone does not suffice. There is demanded also a second requirement that engineering students be imbued with the habits of thought and attitudes needed to proceed effectively from theory to synthesis to practical conclusion. A balanced combination of deep scientific knowledge with true creativity and the ability to innovate is not often found nor easily taught. Many students simply do not have the talent to develop in both these directions simultaneously. This is at the heart of the challenge to engineering school faculties and it is not an easy one. The challenge to the new graduate is equally difficult if he is called on to work in a development program which is crowding the boundaries of technology and for which there is no established base. The number of engineers who can truly work creatively at these boundaries is pitifully small. Each day advanced development programs in the United States slip for lack of viable technical leadership of this type. This leadership must be found if we wish to go forward at the pace which is projected. I believe that it can be found, but only at the price of very hard work. I doubt if young people in any age have faced a greater challenge. I invite you to accept this challenge.

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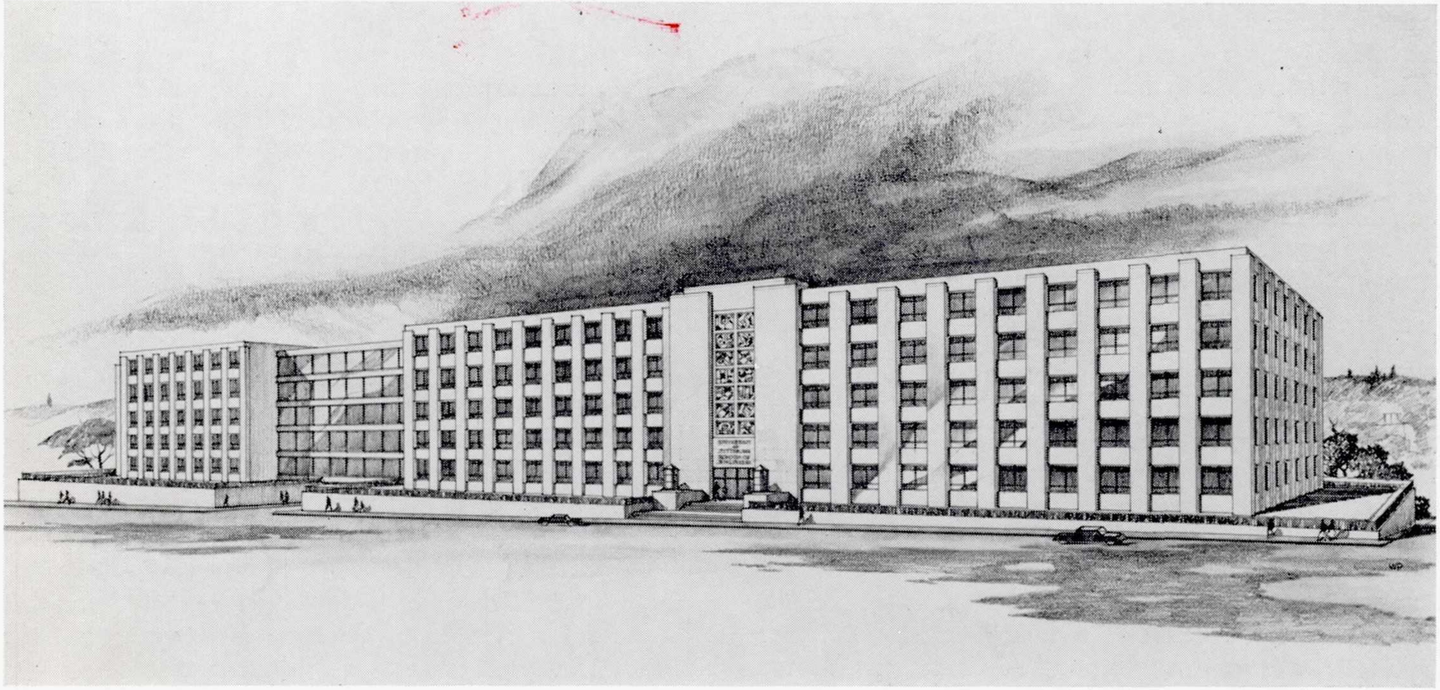

The architect's drawing of the new Engineering and Mines Building to be completed in 1967.

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